

mentation, a DC voltage of 100 to 500 V will be sufficient to generate the desired field strength without causing discharge between electrodes. Also, an additional RF voltage could be applied with these DC voltages (thus effectively providing a focusing field at an independent frequency).

[0076] In this arrangement as well as in the other inventive arrangements, the run length H is preferentially small, with dimensions around 0.1 to 20 mm, typically about 1 mm, such that the mean free path of ions is usually shorter than the relevant dimensions of the conduit.

[0077] As opposed to the arrangement of FIG. 6 that can be tuned to preferentially transmit A or C type ions, the simpler arrangement of FIG. 7 will not show a significant bias regarding differential ion mobility characteristics of ions, but simply improve transmission of all charged particles.

[0078] A similar effect can be achieved by adjustment of the FIG. 6 arrangement to the conditions for transmission of B-type ions (that is with the voltages set such that no distinct high and low field regions are created).

[0079] In an alternative mode of operation the apparatus of FIG. 7 could be directly operated with an alternating high and low field waveform, thus creating an RF FAIMS device, where the field variation with space is translated into a field variation with time that is roughly equivalent when observed from the moving coordinate system of the charged particles.

[0080] The arrangement of first and second electrodes of the focusing/guide structure may be modified to achieve certain objectives. For example, FIG. 8 depicts a top view of a focusing/guide structure 400 composed of first electrodes 405 and second electrodes 410, in which adjacent ring electrodes are laterally offset from each other to define a sinuous ion trajectory (depicted as phantom line 415). Alternatively, the axis of the structure could be gradually bent. By creating bends in the ion trajectory, some ion-neutral separation may be achieved (due to the differential effect of the electric fields), thereby enriching the concentration of ions in the gas/ion stream. In another variant of the focusing/guide structure, first and second electrodes having inner diameters of progressively reduced size may be used to create an ion funnel structure similar to that disclosed in U.S. Pat. No. 6,583,408 to Smith et al., but which utilizes alternating DC fields in place of the conventional RF fields.

[0081] Referring back to FIG. 1, the differential pumping arrangement 130 will now be described in further detail.

[0082] As has been discussed, conventional inlet sections having atmospheric pressure ionization sources suffer from a loss of a majority of the ions produced in the sources prior to the ions entering ion optics for transport into filtering and analyzing sections of mass spectrometers. It is believed that high gas flow at an exit end of the ion transfer arrangement is a contributing factor to this loss of high numbers of ions. The neutral gas undergoes an energetic expansion as it leaves the ion transfer tube. The flow in this expansion region and for a distance upstream in the ion transfer tube is typically turbulent in conventional inlet sections. Thus, the ions borne by the gas are focused only to a limited degree in the ion inlet sections of the past. Rather, many of the ions are energetically moved throughout a volume of the flowing gas. It is postulated that because of this energetic and turbulent flow and the resultant mixing effect on the ions, the ions are not focused to a desirable degree and it is difficult to separate the ions from the neutral gas under these flow conditions. Thus, it is difficult to separate out a majority of the ions and move them downstream while the neutral gas is pumped away. Rather, many of

the ions are carried away with the neutral gas and are lost. On the other hand, the hypothesis associated with embodiments of the present invention is that to the extent that the flow can be caused to be laminar along a greater portion of an ion transfer tube, the ions can be kept focused to a greater degree. One way to provide the desired laminar flow is to remove the neutral gas through a sidewall of the ion transfer tube so that the flow in an axial direction and flow out the exit end of the ion transfer tube is reduced. Also, by pumping the neutral gas out of the sidewalls to a moderate degree, the boundary layer of the gas flowing axially inside the ion transfer tube becomes thin, the velocity distribution becomes fuller, and the flow becomes more stable.

[0083] One way to increase the throughput of ions or transport efficiency in atmospheric pressure ionization interfaces is to increase the conductance by one or more of increasing an inner diameter of the ion transfer tube and decreasing a length of the ion transfer tube. As is known generally, with wider and shorter ion transfer tubes, it will be possible to transport more ions into the ion optics downstream. However, the capacity of available pumping systems limits how large the diameter and how great the overall conductance can be. Hence, in accordance with embodiments of the present invention, the inner diameter of the ion transfer channel 115 (FIG. 1) can be made relatively large and, at the same time, the flow of gas out of the exit end of the ion transfer channel 115 can be reduced to improve the flow characteristic for keeping ions focused toward a center of the gas stream. In this way, the neutral gas can be more readily separated from the ions, and the ions can be more consistently directed through the exit orifice 70 into MS1 downstream. The result is improved transport efficiency and increased instrument sensitivity.

[0084] Even if it is found in some or all cases, that turbulent flow results in increased ion transport efficiency, it is to be understood that decreased pressure in a downstream end of the ion transfer channel and increased desolvation due to the decreased pressure may be advantages accompanying the embodiments of the present invention under both laminar and turbulent flow conditions. Furthermore, even with turbulent flow conditions, the removal of at least some of the neutral gas through the sidewall of the ion transfer tube may function to effectively separate the ions from the neutral gas. Even in turbulent flow, the droplets and ions with their larger masses will most likely be distributed more centrally during axial flow through the conduit 60. Thus, it is expected that removal of the neutral gas through the sidewalls will effectively separate the neutral gas from the ions with relatively few ion losses under both laminar and turbulent flow conditions. Still further, the removal of latent heat by pumping the neutral gas through the sidewalls enables additional heating for increased desolvation under both laminar and turbulent flow conditions.

[0085] Region 2 containing the conduit 60 is preferably pumped from pumping port 55. As may be seen in FIG. 1, the differential pumping arrangement 130 comprises a plurality of passageways 140 for fluid communication between the interior region containing the channel 115, and the vacuum chamber 50 containing the conduit 60 in Region 2. Neutral gas is pumped from within the interior region 115 and out through the passageways 140 in the differential pumping arrangement 130 into the vacuum chamber 50 where it is pumped away.

[0086] A sensor may be connected to the ion transfer conduit 60 and to a controller 58 for sending a signal indicating a temperature of the sidewall or some other part of the ion